

PROCEEDINGS
OF THE
CALIFORNIA ACADEMY OF SCIENCES

Vol. 44, No. 12, pp. 269-282, 18 figs.

May 6, 1986

LATE CENOZOIC MARINE MOLLUSKS FROM TUFF
CONES IN THE GALÁPAGOS ISLANDS

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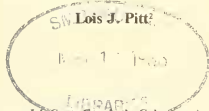
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ABSTRACT: Palagonite tuff cones on Isla Santa Cruz in the Galápagos Archipelago have yielded fossil marine mollusks, preserved both as individual shells with tuff infillings and as larger fossiliferous limestone inclusions. Twenty species (19 gastropods and 1 bivalve) are reported from the Cerro Gallina tuff cone, and representative specimens are illustrated. Two of the nominal species are known only as fossils from the Galápagos; the remaining nominal species are living today, although not necessarily in the archipelago. The two modes of preservation in Galápagos tuff cones reflect two different age relationships between the fossils and the enclosing pyroclastic rock: the individual fossils are more or less contemporaneous with the tuff matrix, while the larger fossiliferous inclusions are incorporated from an older limestone formation. The subaqueously formed and subsequently uplifted tuff cones represent an earlier phase of Galápagos volcanism than the younger Bruhnes-age volcanoes and subaerial flows that dominate the emergent surfaces of the islands today, although geologic evidence suggests that they may have formed no earlier than about 3 million years ago.

INTRODUCTION

Igneous rocks seldom contain fossils, and oceanic islands of volcanic origin seldom pre-

serve fossil records of their contemporaneous biotas. Although the geologic history of the Galápagos Archipelago is dominated by volcanic activity, there are at least five distinctive sedimentary settings in which remains of marine organisms have been preserved (Lipps and Hickman 1982; Hickman and Lipps 1985). In

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addition, there is one volcanic setting that has preserved marine fossils in an unusual manner: palagonite tuff cones, massive topographic structures formed from the products of submarine pyroclastic volcanism but incorporating occasional isolated shells and larger fossiliferous limestone inclusions. In this paper we provide the first systematic documentation and illustration of tuff cone faunas in the Galápagos, along with a brief discussion of their occurrence, distribution, and mode of fossilization.

This report (contribution number 366 of the Charles Darwin Foundation) is based on a paleontological reconnaissance expedition to the Galápagos during February 1982, organized by the senior author and including the remaining authors as participants (see also Pitt and James 1983; Pitt 1984). We thank the Galápagos National Park Service, the Charles Darwin Research Station and its former directors, D. C. Duffy and F. Koster, and Ecuadorian military officials for their cooperation and assistance. We are grateful to A. and J. DeRoi for calling our attention to the presence of marine shells in the tuff cone at Cerro Gallina. Our research has been supported in part by the Committees on Research, University of California, Berkeley and Davis, and the Museum of Paleontology, University of California, Berkeley.

GEOLOGIC SETTING

There are six major tuff cones and tuff cone complexes ringing Isla Santa Cruz, a large, low island near the center of the young, active volcanic archipelago (Fig. 1). The cones are primarily of submarine origin and represent an earlier, subsequently uplifted phase of Galápagos volcanism than the younger cinder cones, volcanoes, and subaerial flows (McBirney and Williams 1969; Bow 1979). The uplifted cones are now deeply eroded and dissected, emerging as islands from more recent subaerial basalt flows. Although one of the cones is now situated 1 km inland from the modern shoreline (Bow 1979), the others have conspicuous wave-cut exposures and stand out as landmarks along the coast.

The absolute age and contemporaneity of the tuff cones on Santa Cruz have not been demonstrated. These cones occur below Bruhnes paleomagnetic-age flows of the late Pleistocene and Recent and may represent Matuyama-age volcanism. However, the oldest radiometric date

that has been obtained in the archipelago is a potassium-argon date of 4.8 ± 1.87 mybp on the palagonite tuff on South Plazas, part of the Cerro Colorado cone complex (Cox and Dalrymple 1966; Cox 1983). Examination of fossiliferous inclusions in the tuff and consideration of Matuyama-age dates associated with the inferred source of the inclusions (Cox and Dalrymple 1966; Cox 1983) lead us to reject the Plazas date (which is inherently questionable in its large standard deviation).

We examined and collected fossils from two of the tuff cones, Cerro Gallina and Cerro Colorado. The more abundant and diverse material was from Cerro Gallina, and it is this fauna that is treated systematically and illustrated below.

The geology of Cerro Colorado is more complicated. Here we also observed and collected fossil mollusks from a prominent, richly fossiliferous limestone bed, originally reported by Durham (1965), that crops out north of and in faulted contact with the main tuff cone complex (see Hickman and Lipps 1985). The faunas of the fossiliferous limestone and tuffaceous sandstone beds on Santa Cruz and Isla Baltra merit separate consideration and are not treated in this report. Earlier California Academy of Sciences collections from these settings on Baltra and Santa Cruz were described by Dall (1924), Dall and Ochsner (1928), Hertlein and Strong (1939), and Hertlein (1972); Durham (1979) described a new species of *Haliotis* from the limestone at Cerro Colorado. Durham's collections are housed in the Museum of Paleontology, University of California, Berkeley.

CERRO GALLINA.—Cerro Gallina stands out as a dissected red hill of bedded lapilli tuffs rising approximately 100 m above sea level on the southwest coast of Isla Santa Cruz (00°42'50"S; 90°29'50"W). Fossils occur as isolated whole shells within the tuff from the base of the exposed cone at sea level to its eroded summit. A fauna of 20 species (19 gastropods and 1 bivalve) was collected.

CERRO COLORADO.—Cerro Colorado (Fig. 2), a reddish brown eroded tuff cone remnant, is a conspicuous landmark on the eastern coastline of Santa Cruz (00°34'30"S; 90°10'20"W). It is part of a larger tuff cone complex that includes at least two distinct vents (Bow 1979). The Island of South Plazas is an offshore remnant of this complex. Although fossils are less abundant in the tuff at Cerro Colorado than at Cerro Gallina,

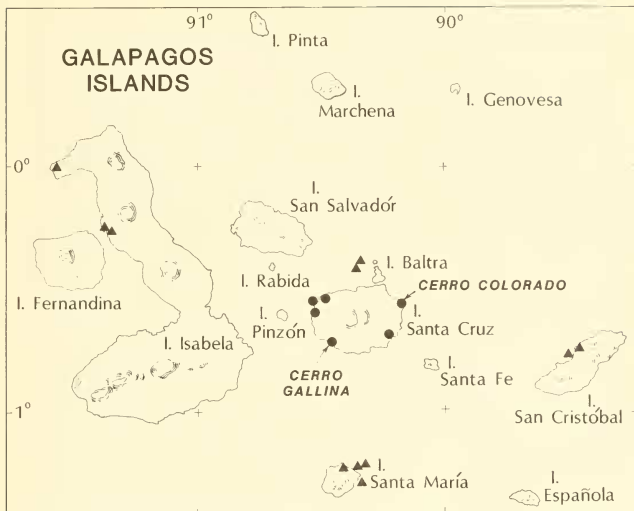


FIGURE 1. Map of the Galápagos Islands showing locations of palagonite tuff cones (dots) on Isla Santa Cruz, including Cerro Gallina and Cerro Colorado. Some additional tuff cones on other islands are also shown (triangles).

their distribution and mode of preservation is more interesting. In some of the well-sorted facies more distal to the main Cerro Colorado vent (Fig. 3), we found individual fossil shells, although the proximal tuff on the mainland is largely unfossiliferous. On South Plazas, in poorly sorted facies proximal to the second vent, fossils also occur as isolated individual shells (Fig. 4), but they are more prominent as large fossiliferous limestone inclusions (Fig. 5) that have been incorporated from an older fossiliferous limestone that is lithologically and faunally similar to limestone cropping out in the cliffs immediately north of Cerro Colorado.

OTHER FOSSILIFEROUS TUFF CONES.—More detailed examination of tuff cones in the Galápagos may expand the fauna reported here. Bow (1979) studied several of the tuff cones on Santa Cruz that we did not visit and reported incor-

poration of exotic blocks of limestone coquina up to several meters across. Although Darwin apparently did not personally observe or collect fossil material from tuff cones in the Galápagos, he reported (1844) receiving shell fragments imbedded in tuff from an officer who collected them "several hundred feet" above sea level on San Cristóbal. Darwin did, however, study the tuffs from the San Cristóbal cones as well as those on Santiago and Isabela, and was the first geologist to recognize that they had formed subaqueously (Darwin 1844). Fossils have not been reported from the tuff cones on Isla Isabela, and we saw no trace of shell material in our exploration of the Tagus cone complex.

FOSSILIZATION IN VOLCANIC ROCKS

Because volcanic rocks form from molten material, they do not normally contain fossils, al-

though there are scattered reports of fossils preserved in predominantly igneous settings.

There are peculiar tectonic environments in which marine mollusks have been preserved within thick sequences of oceanic basalt, notably in Oregon and Washington where Tertiary volcanic sequences have been accreted to the North American continent over a subduction zone (Hickman and Lindberg 1984). Hickman (1976) described two new species of *Pleurotomaria* from the Siletz River Volcanics in Oregon and figured fragments of two additional species from the Crescent Formation, a thick (at least 5,000 m) Eocene volcanic sequence in northwestern Washington. Individual fossils are not, however, encased in basalt, but occur characteristically in thin limestone lenses or tuffaceous agglomerates within the basalt. Snavely and Baldwin (1948) reported marine mollusks from tuffaceous interbeds in the Siletz River Volcanics; tuffaceous agglomerates in the Crescent Formation also preserve foraminifera (Berthiaume 1938) and corals (Durham 1942), as well as marine mollusks.

Direct incorporation of organic remains into volcanogenic rocks is more difficult and less common. Subaerial ash falls provide one mechanism for rapidly burying organisms in a medium that has cooled sufficiently to be nondestructive. Pompeii and Herculaneum are modern examples of the same process that enveloped successive forests of tree trunks in the Eocene of Yellowstone National Park.

Closer to the molten state, tree trunks do occasionally leave molds in rapidly cooling basalt flows, where total destruction of volatile organic matter is not complete until the lava is sufficiently chilled to preserve the empty space as a hollow tube. There is also the famous mold of a bloated rhinoceros in Miocene Columbia River Basalts in eastern Washington (Beck 1937; Chappell et al. 1949, 1951). Again, this fossil was preserved under very special circumstances involving rapid chilling of the lava.

Finally, there are several accounts of fossils preserved in volcanic rocks as inclusions. Late Quaternary fossiliferous xenoliths in the subaerially deposited tephra of Surtsey have been discussed in a series of reports dealing with this historic volcanic event (Alexandersson 1970, 1972; Simonarson 1974). Fossiliferous inclusions also occur on adjacent Heimaey in the older Vestmann Islands (Jakobsson 1968; Simonarson

1982), and were apparently carried upward in the hot magma to be ejected to their current elevation as these volcanoes emerged from the sea.

The individual fossil shells and the fossiliferous limestone inclusions in the subaqueously formed Galápagos tuff cones represent yet another mode of preservation of organic remains in a volcanic setting. Our knowledge of the physical and chemical process by which basaltic magmas are palagonitized and subaqueous tuff cones formed is based primarily on studies in the Galápagos (McBirney and Williams 1969; Simkin 1984). It is therefore appropriate to consider the organic component of these otherwise well-known volcanic structures.

GALÁPAGOS TUFF CONE FORMATION AND INCORPORATION OF SHELLS AND FOSSILS

Explosive submarine volcanism of the type that produced the Galápagos tuff cones is atypical of the current eruptive mode in the archipelago, being more typical of convergent plate boundaries than of spreading centers and hot spots (see Simkin 1984, for a review of eruptive styles and products in the Galápagos). On Santa Cruz we observed two main types of fragmental deposits resulting from explosive volcanism: relatively young, steep-sided, cinder cones that formed subaerially; and older, consolidated, tuff deposits with more subdued, broader profiles that formed subaqueously when gaseous magma erupted from shallow submarine vents.

There are two different ways that molluscan shells have become incorporated into the Galápagos tuffs: (1) as living or recently dead individuals that were on the surface or in unconsolidated sediment adjacent to the vent at the time of eruption, or (2) as blocks of older fossiliferous rock that were incorporated into the tuff as it formed.

At Cerro Gallina, fossils occur as isolated shells with infillings of palagonite tuff. These shells were therefore empty at the time of eruption and were infilled and incorporated into the cones during the episodes of cold-water quenching, volumetric expansions and fragmentation, chemical alteration, and cone building.

The palagonite tuffs associated with both vents in the Cerro Colorado tuff cone complex contain isolated infilled shells similar to those at Cerro Gallina. Examination of a thin section of one of



FIGURES 2–6. Galápagos tuff cones and mode of occurrence and preservation of fossil material. Figure 2. Cerro Colorado, eroded tuff cone remnant on the east coast of Isla Santa Cruz. Figure 3. Seachiff exposure of well-bedded distal facies of a portion of the eroded tuff cone at Cerro Colorado. Figure 4. Individual fossil shell in tuff matrix (at arrow) on South Plazas, Cerro Colorado tuff cone complex. Figure 5. Fossiliferous limestone inclusion in tuff on South Plazas. Figure 6. Thin section of fossil strombid gastropod from the Cerro Colorado tuff cone. a. Outer shell layers showing loss of original microstructure. b. Inner shell layers showing well-preserved crossed-lamellar microstructure. Scale bar = 160 μ m.

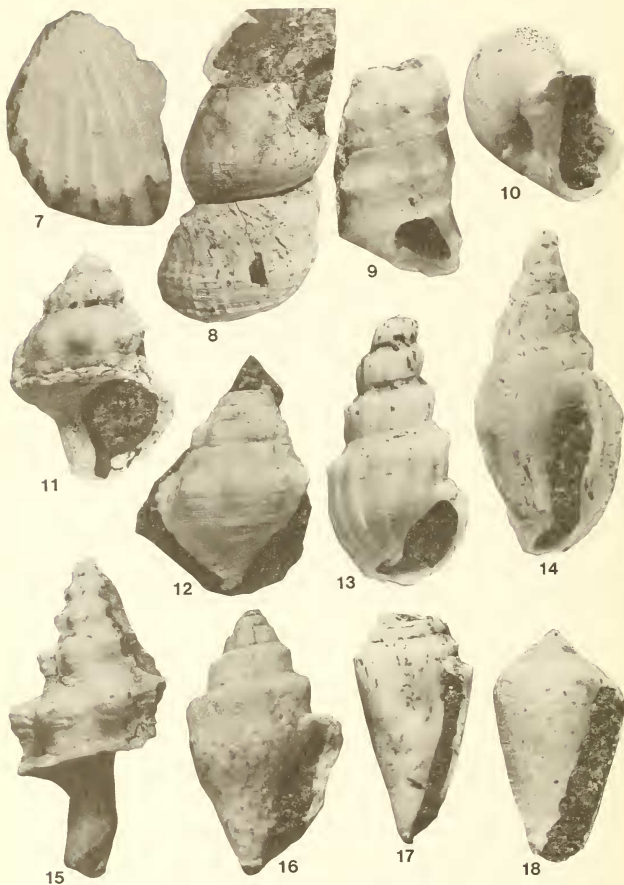
these shells (Fig. 6) shows alteration of both the innermost and outermost layers where they are in contact with the tuff matrix. The alteration consists of a loss of shell microstructure (Fig. 6a) in contrast to the well-preserved original crossed-lamellar structure of the interior layers (Fig. 6b).

In addition to isolated shells (Fig. 4), which are most evident in the better-sorted and better-bedded distal facies at Cerro Colorado, there are older xenoliths in the form of fossiliferous lime-

stone boulders (Fig. 5). The boulders were incorporated into the tuff as the magma erupted through older rocks, and they are analogous to those found on Surtsey except that they were incorporated subaqueously rather than blown out subaerially.

PALEOECOLOGY AND TAPHONOMY

The tuff cone mollusks are primarily assigned to species that are alive today and restricted to



FIGURES 7-18. Fossil mollusks from Cerro Gallina, Isla Santa Cruz. Figure 7. *Trigonocardia?* sp. CAS Geology 61411, CAS Loc. 61227, length 11.5 mm. Figure 8. *Turritella broderipiana marmorata* Kiener, 1843, CAS Geology 61412, CAS Loc. 61226, length 61.4 mm. Figure 9. *Turritella rubescens* Reeve, 1849, CAS Geology 61413, CAS Loc. 61233, length 11.4 mm. Figure

depths of less than 100 meters. Many of the shells in the Cerro Gallina tuff show signs of post-mortem infestation by boring organisms (Fig. 7–9, 11–13, 16), suggesting that they were exposed for a period of time prior to burial. Most of the shells are entire, and we did not encounter fragmented shell debris suggestive of extensive exposure and transportation. The fauna is, however, dominated by relatively thick-shelled species with morphologies resistant to post-mortem destruction.

SYSTEMATIC PALEONTOLOGY

The specimens upon which this study is based are deposited in the Department of Geology, California Academy of Sciences (CAS). Voucher specimen numbers are assigned only to figured specimens. All specimens bear Academy locality numbers, and complete locality descriptions are provided in the Appendix and in the locality register maintained in the Department of Invertebrates and Geology. Representative fossil specimens from the tuff cones will also be deposited in the reference collection at the Charles Darwin Research Station, Isla Santa Cruz, Galápagos. Comparative discussion of taxa treated below is based on examination of material in Academy collections.

Class PELECYPODA
Subclass HETERODONTA
Order VENEROIDA
Superfamily CARDIACEA
Family CARDIIDAE
Subfamily FRAGINAE
Genus *Trigonocardia* Dall, 1900

Trigonocardia? sp.

(Figure 7)

DISCUSSION.—This taxon is represented by a single worn partial valve. Sculpture consists of flattened, scaled ribs with narrow, finely cross-

threaded interspaces as in *Trigonocardia biangulata* (Broderip and Sowerby, 1829). This specimen is not as convex as in typical *Trigonocardia* and lacks all of the hinge region, making positive generic and specific allocation impossible without additional material.

DISTRIBUTION.—Galápagos Islands, fossil.

GEOLOGIC OCCURRENCE.—Pleistocene.

LOCALITY.—CAS Loc. 61227.

FIGURED SPECIMEN (incomplete).—CAS Geology No. 61411. Length 11.5 mm; width 8.6 mm.

Class GASTROPODA
Order MESOGASTROPODA
Superfamily TURRITELLACEA
Family TURRITELLIDAE
Subfamily TURRITELLINAE
Genus *Turritella* Lamarck, 1799

Turritella broderipiana marmorata Kiener, 1843 (Figure 8)

Turritella broderipiana Orbigny, 1840:388.

Turritella marmorata Kiener, 1843:23, pl. 8, fig. 1.

Turritella broderipiana marmorata Kiener. Hertlein 1972:41–42, fig. 26–28.

DISCUSSION.—*Turritella broderipiana* was originally described but not illustrated, leading to difficulties recognizing the taxon and assessing its relationship to the subsequently described *T. marmorata* on one hand and *T. gonostoma* Valenciennes, 1832 on the other. Our fossil specimens from the Galápagos are most similar to Kiener's (1843) illustrations of *T. marmorata*, but the above synonymy does not resolve all the problems attending use of the three available names. We summarize these problems below.

Reeve (1849, species 6, pl. 2, fig. 6A, B) figured specimens that he assigned to *Turritella broderipiana* and *T. marmorata* and placed Kiener's name in synonymy with *T. broderipiana*. Keen (1958:290, fig. 183, and 1971:392, fig. 438) figured the holotype of *T. broderipiana* and came to a conclusion counter to that of Reeve: that *T. marmorata* was a synonym of the more northern

10. *Polinices uber* (Valenciennes, 1832), CAS Geology 61414, CAS Loc. 61235, length 19.9 mm. Figure 11. *Bursa caelata* (Broderip, 1833), CAS Geology 61415, CAS Loc. 61225, length 45.1 mm. Figure 12. *Cantharus sanguinolentus* (Duclos, 1833), CAS Geology 61416, CAS Loc. 61225, length 30.3 mm. Figure 13. *Phos laevigatus* (A. Adams, 1851), CAS Geology 61417, CAS Loc. 61235, length 30.0 mm. Figure 14. *Strombina lanceolata* (Sowerby, 1832), CAS Geology 61406, CAS Loc. 61225, length 17.4 mm. Figure 15. *Latirus centrifugus* (Dall, 1915), CAS Geology 61407, CAS Loc. 61225, length 29.2 mm. Figure 16. *Columbella castanea* Sowerby, 1832, CAS Geology 61408, CAS Loc. 61225, length 24.1 mm. Figure 17. *Conus (Asprella) arcuatus* Broderip and Sowerby, 1829, CAS Geology 61409, CAS Loc. 61235, length 25.3 mm. Figure 18. *Conus (Cylindrus) lucidus* Wood, 1828, CAS Geology 61410, CAS Loc. 61225, length 25.2 mm.

species *T. gonostoma* rather than the southern *T. broderipiana*.

Hertlein (1972) elected another alternative when he recognized the subspecies *Turritella broderipiana marmorata* for specimens from Peru as well as specimens from Late Cenozoic deposits on Isla Baltra, Galápagos Islands. We have followed Hertlein in our identification of specimens from Cerro Gallina because they compare most closely with Hertlein's material from the adjacent Isla Baltra as well as with CAS specimens from Peru.

Both *Turritella broderipiana* and *T. gonostoma* have been characterized as highly variable (Merriam 1941:9), and evaluation of the species complex is beyond the scope of this paper. In Recent populations, color pattern has been used to separate the two species. The taxonomic significance of pigmentation has not been evaluated, however, and cannot be used to distinguish fossil specimens. Additional material from mainland Ecuador and Peru, where the geographic ranges of the two color-forms overlap, may eventually help resolve this problem.

DISTRIBUTION.—Ecuador to Peru, living and fossil.

GEOLOGIC OCCURRENCE.—Miocene(?)–Recent.

LOCALITIES.—CAS Locs. 61225, 61226, 61238.

MATERIAL COLLECTED.—Five specimens.

FIGURED SPECIMEN.—CAS Geology No. 61412 (Loc. 61226).
Length 61.4 mm; width 32.8 mm.

***Turritella rubescens* Reeve, 1849**

(Figure 9)

Turritella rubescens Reeve, 1849, vol. 5, pl. 11, sp. 63; Keen 1958:290, fig. 187, as synonym of *T. nodulosa* King and Broderip 1832; Keen 1971:394, fig. 445.

DISCUSSION.—Specimens from Cerro Gallina match the original figure of Reeve (1849) and the lower figure of Keen (1971), which illustrates a syntype from the British Museum (Natural History). The four figures of Keen (1971:445) indicate the variability of this species.

DISTRIBUTION.—Gulf of California to Colombia, living; Galápagos Islands, fossil.

GEOLOGIC OCCURRENCE.—Pleistocene–Recent.

LOCALITIES.—CAS Locs. 61225, 61233.

MATERIAL COLLECTED.—Three specimens.

FIGURED SPECIMEN.—CAS Geology No. 61413 (Loc. 61233).
Length 11.4 mm; width 6.8 mm.

Superfamily NATICACEA

Family NATICIDAE

Genus *Polinices* Montfort, 1810

Subgenus *Polinices* sensu stricto

Polinices (Polinices) uber (Valenciennes, 1832)

(Figure 10)

Natica uber Valenciennes, 1832:266.

Polinices uber (Valenciennes, 1832). Carpenter 1857:452–453; Dall and Ochsner 1928:96–97; Hertlein and Strong 1939:370.

Polinices (Polinices) uber (Valenciennes, 1832). Keen 1958:323, fig. 272; Keen 1971:480, fig. 882.

DISCUSSION.—Two incomplete specimens of this species were collected from Cerro Gallina. On one specimen the spire is low, the body whorl globose and smooth, the columellar callus thin, and the umbilicus deep. This specimen does not have a funicle, and the outer lip is missing. Marinovich (1977) discussed the complex relationships of *P. uber*, *P. intemeratus* (Philippi, 1853) and *P. unimaculatus* (Reeve, 1855).

DISTRIBUTION.—Cedros Island, western Baja California, throughout the Gulf of California, and south to the Galápagos and Paita, Peru, living; Imperial Formation of California and Galápagos Islands, fossil.

GEOLOGIC OCCURRENCE.—Pliocene–Recent.

LOCALITIES.—CAS Locs. 61235, 61238.

MATERIAL COLLECTED.—Two specimens.

FIGURED SPECIMEN.—CAS Geology No. 61414 (Loc. 61235).
Length 19.9 mm; width 17.2 mm.

Superfamily CYMATIACEA

Family BURSIDAE

Genus *Bursa* Röding, 1798

Bursa caelata Broderip, 1833

(Figure 11)

Ranella caelata Broderip, 1833:179.

Bursa caelata (Broderip, 1833). Keen 1958:347, fig. 327; Keen 1971:508, fig. 964.

DISCUSSION.—Four incomplete fossil specimens from the Cerro Gallina tuff cone are most similar morphologically to specimens of the Recent *Bursa caelata* (Broderip, 1833). The fossils have three nodes between varices, four on some of the earlier whorls. Spiral sculpture is worn, but there are indications of possible secondary nodes. Varices are too worn to show sculpture pattern. The typical Recent specimen of *B. caelata* has numerous primary nodes at the shoulder, with rows of secondary nodes above and below the shoulder, and several rows below the shoulder on the body whorl. Some specimens in lots from Panama and Costa Rica have only three nodes between varices and have few secondary spirals and nodes. The fossil specimens are not complete enough to obtain accurate measurements. However, proportions are very close to

those of Recent conspecific specimens in the CAS collections.

DISTRIBUTION.—Gulf of California to Peru, living; Galápagos Islands, fossil.

GEOLOGIC OCCURRENCE.—Pleistocene–Recent.

LOCALITIES.—CAS Locs. 61225, 61234.

MATERIAL COLLECTED.—Five specimens.

FIGURED SPECIMEN.—CAS Geology No. 61415 (Loc. 61225). Length 45.1 mm; width 31.8 mm.

Superfamily BUCCINACEA

Family BUCCINIDAE

Genus *Cantharus* Röding, 1798

Subgenus *Gemophos* Olsson and Harbison, 1953

Cantharus (*Gemophos*) *sanguinolentus* (Duclos, 1833)

(Figure 12)

Purpura sanguinolentus Duclos, 1833, pl. 22, fig. 1.

Cantharus sanguinolentus (Duclos, 1833). Keen 1958:400, fig. 539; Keen 1971:561, fig. 1115.

DISCUSSION.—The single specimen collected at Cerro Gallina is incomplete, lacking the early whorls, outer lip, and anterior canal. A comparison was made between our specimen and *Cantharus janellii* (Kiener, 1835–36). Our specimen has low elongated nodes at the shoulder, while *C. janellii* has more pronounced and rounder nodes. The spiral sculpture is variable and should not be considered a diagnostic feature. Differences between these two species are in the node at the shoulder, the columellar markings, and the color (*C. sanguinolentus* has columellar pustules while *C. janellii* has columellar plications). Also, *C. sanguinolentus* has a pink columella whereas *C. janellii* has a black columella.

DISTRIBUTION.—Outer coast of Baja California through the southern part of the Gulf of California to Guaymas, Mexico, and south to the Ecuadorian mainland, living; Galápagos Islands, fossil.

GEOLOGIC OCCURRENCE.—Pleistocene–Recent.

LOCALITY.—CAS Loc. 61225.

FIGURED SPECIMEN.—CAS Geology No. 61416. Length 30.3 mm; width 21.5 mm.

Genus *Engina* Gray, 1839

Engina pyrostoma (Sowerby, 1832)

(Not figured)

Columbella pyrostoma Sowerby, 1832:116–117 (not illustrated).

Engina pyrostoma (Sowerby, 1832). Keen 1971:565, fig. 1128; Hertlein 1972:29.

DISCUSSION.—The single specimen collected at Cerro Gallina is worn and incomplete. Never-

theless, it exhibits sufficient morphological similarity to Recent specimens of *Engina pyrostoma* to warrant recognizing it as a fossil representative of this endemic Galápagos taxon.

DISTRIBUTION.—Galápagos Islands, living and fossil.

GEOLOGIC OCCURRENCE.—Pliocene–Recent.

LOCALITY.—CAS Loc. 61236.

Genus *Phos* Montfort, 1810

Subgenus *Metaphos* Olsson, 1964

Phos (*Metaphos*) *laevigatus* A. Adams, 1851

(Figure 13)

Phos laevigatus Adams, 1851:155 (not figured, but see Emerson 1967, for discussion of subsequent figuring of the type specimen).

Phos chelonina Dall, 1917:578. Strong and Lowe 1936:310, pl. 22, fig. 3 (holotype).

Metaphos laevigatus (Adams, 1851). Emerson 1967:99–102, pl. 13, fig. 1–8.

Phos (*Metaphos*) *laevigatus* (Adams, 1851). Keen 1971:569, fig. 1145.

DISCUSSION.—The single specimen from Cerro Gallina lacks early whorls and the anterior canal, and fine shell sculpture details are worn. When whole, it had approximately eight whorls, 14 rounded axials, and a weakly tabulate shoulder sloping to the suture giving the effect of being slightly noded; spirals numerous, whorls straight-sided, body whorl tapering on anterior one-third.

DISTRIBUTION.—Galápagos Islands, living and fossil.

GEOLOGIC OCCURRENCE.—Pleistocene–Recent.

LOCALITY.—CAS Loc. 61235.

FIGURED SPECIMEN.—CAS Geology No. 61417. Length 30.0 mm; width 15.5 mm.

Family COLUMBELLIDAE

Genus *Columbella* Lamarck, 1799

Columbella cf. *C. strombiformis* Lamarck, 1822

(Not figured)

DISCUSSION.—The single specimen from Cerro Gallina is missing about one-quarter turn from the outer lip and part of the anterior canal. In general outline, the specimen resembles *Columbella strombiformis*. Aperture shape is also similar to that of *C. strombiformis* when the missing portion of the shell is taken into consideration.

DISTRIBUTION.—Galápagos Islands.

GEOLOGIC OCCURRENCE.—Pleistocene.

LOCALITY.—CAS Loc. 61225.

***Columbella castanea* Sowerby, 1832**

(Figure 16)

Columbella castanea Sowerby, 1832:118; Keen 1971:574, fig. 1154.

DISCUSSION.—*Columbella castanea* differs from other Panamic columbellids in its turreted whorl profile. The single specimen from Cerro Gallina has a second slight angulation at the suture that is more pronounced than on living specimens. *Columbella major* Sowerby, 1832, which we also collected as a Pleistocene fossil in terrace deposits on Isla Santa Fe, is distinguished by its rounder periphery and straighter-sided spire profile.

DISTRIBUTION.—Galápagos Islands, living and fossil.

GEOLOGIC OCCURRENCE.—Pleistocene–Recent.

LOCALITY.—CAS Loc. 61225.

FIGURED SPECIMEN.—CAS Geology No. 61408. Length 24.1 mm; width 14.2 mm.

Genus *Anachis* H. and A. Adams, 1853***Anachis*? sp. indet.**

(Not figured)

DISCUSSION.—An incomplete specimen, tentatively assigned to the genus *Anachis*, was collected from Cerro Gallina. The specimen has 14 low, axial ribs that become obsolete below the periphery, where they are replaced by numerous fine, raised spirals. The columella is smooth with a light callus, the aperture is narrow with a rather deep posterior notch, and the outer lip is lirate within.

DISTRIBUTION.—Galápagos Islands, fossil.

GEOLOGIC OCCURRENCE.—Pleistocene.

LOCALITY.—CAS Loc. 61225.

Genus *Strombina* Mörch, 1852**Subgenus *Strombina* sensu stricto*****Strombina* (*Strombina*) *lanceolata* Sowerby, 1832**

(Figure 14)

Columbella lanceolata Sowerby, 1832:116 (not illustrated).*Strombina lanceolata* (Sowerby, 1832). Keen 1958:394.*Strombina* (*Strombina*) *lanceolata* (Sowerby, 1832). Keen 1971:601, fig. 1275.*Strombina recurva* Sowerby, Dall and Ochsner (1928:96) [not *Strombina recurva* (Sowerby, 1832)].*Strombina gibberula* Sowerby, Hertlein (1972:29) [not *Strombina gibberula* (Sowerby, 1832)].

DISCUSSION.—This is one of the most abundant species in the fauna at Cerro Gallina. Specimens compare favorably both with modern rep-

resentatives of the species and with specimens from Isla Baltra that were originally assigned by Dall and Ochsner (1928) and Hertlein (1972) to other species of *Strombina* (see synonymy).

DISTRIBUTION.—Ecuadorian mainland to Galápagos Islands, living and fossil.

GEOLOGIC OCCURRENCE.—Pliocene–Recent.

LOCALITIES.—CAS Locs. 61225, 61234, 61235, 61236, 61237.

MATERIAL COLLECTED.—Eighteen specimens.

FIGURED SPECIMEN.—CAS Geology No. 61406. Length 17.4 mm; width 8.1 mm.

Family NASSARIIDAE**Genus *Nassarius* Duméril, 1806*****Nassarius caelolineatus* Nesbitt and Pitt, 1986**

(Not figured)

Nassarius caelolineatus Nesbitt and Pitt, 1986:294–295, fig. 1, 2, 17a.

DISCUSSION.—Abundant specimens of a nassariid gastropod at Cerro Gallina compare favorably with both living and fossil specimens from the Galápagos that have been assigned to *Nassarius nodocinctus* (A. Adams, 1852). Material from the Galápagos does represent an endemic taxon, but a new name was required because specimens conspecific with the syntypes of *N. nodocinctus* have never been collected in the archipelago.

DISTRIBUTION.—Galápagos Islands, living and fossil.

GEOLOGIC OCCURRENCE.—Pliocene–Recent.

LOCALITIES.—CAS Locs. 61225, 61234, 61236.

MATERIAL COLLECTED.—Twenty-five specimens.

Family FASCIOLARIIDAE**Subfamily FASCIOLARIINAE****Genus *Latirus* Montfort, 1810*****Latirus centrifugus* (Dall, 1915)**

(Figure 15)

Fusinus centrifugus Dall, 1915:56 (not figured).*Latirus centrifugus* (Dall). Keen 1971:613, fig. 1327.

DISCUSSION.—Two fasciolariid specimens collected from different parts of the Cerro Gallina tuff cone have the proportions and characteristic ornamentation of *Latirus centrifugus*. This is the first report of this species as a fossil in the Galápagos. Fasciolarids described by Dall and Ochsner (1928) under *Latirus* from the older Pliocene limestone bed north of Cerro Colorado have shorter anterior canals and different ornamentation.

DISTRIBUTION.—Galápagos Islands, living and fossil.

GEOLOGIC OCCURRENCE.—Pleistocene–Recent.

LOCALITIES.—CAS Locs. 61225, 61234.

MATERIAL COLLECTED.—Two specimens.

FIGURED SPECIMEN.—CAS Geology No. 61407 (Loc. 61225).
Length 29.2 mm; width 14.9 mm.

Superfamily CONACEA

Family CONIDAE

Genus *Conus* Linnaeus, 1758

Subgenus *Asprella* Schaufuss, 1869

Conus (Asprella) arcuatus Broderip and Sowerby, 1829

(Figure 17)

Conus arcuatus Broderip and Sowerby, 1829:379.

Conus (Lithoconus) arcuatus Broderip and Sowerby. Keen 1958:458, fig. 936.

Conus (Asprella) arcuatus Broderip and Sowerby. Keen 1971:663, fig. 1496.

DISCUSSION.—Specimens collected over a range of 40 m elevation in the Cerro Gallina tuff cone preserve the slender profile and turreted, faintly nodulose spire diagnostic of this species.

DISTRIBUTION.—Gulf of California to Panama, living; Costa Rica to Galápagos Islands, fossil.

GEOLOGIC OCCURRENCE.—Pleistocene–Recent.

LOCALITIES.—CAS Locs. 61225, 61234, 61235.

MATERIAL COLLECTED.—Three specimens.

FIGURED SPECIMEN.—CAS Geology No. 61409 (Loc. 61235).
Length 25.3 mm; width 12.8 mm.

Subgenus *Chelyconus* Mörch, 1852

Conus (Chelyconus) orion Broderip, 1833

(Not figured)

Conus orion Broderip, 1833:55; Keen 1958:483 (as a synonym of *Conus vittatus* Bruguière, 1792).

Conus (Chelyconus) orion Broderip, 1833. Keen 1971:664, fig. 1499.

DISCUSSION.—The single specimen from Cerro Gallina is worn but retains the characteristic profile and features of this species.

DISTRIBUTION.—Mexico to Ecuador, living; Galápagos Islands, fossil.

GEOLOGIC OCCURRENCE.—Pleistocene–Recent.

LOCALITY.—CAS Loc. 16237.

Subgenus *Cylindrus* Deshayes, 1824

Conus (Cylindrus) lucidus Wood, 1828

(Figure 18)

Conus lucidus Wood, 1828:8, pl. 3, fig. 4; Hanna 1963:56–58, pl. 6, fig. 1.

Conus loomisi Dall and Ochsner, 1928:103, pl. 2, fig. 6.

Conus (Cylindrus) lucidus Wood, 1828. Keen 1958:484, fig. 933; Keen 1971:664, fig. 1503.

DISCUSSION.—*Conus loomisi* Dall and Ochsner, from Pleistocene terrace deposits on Isla Isabela, is here considered a synonym of *C. (C.) lucidus* because fossil specimens in the CAS collections clearly show the color pattern of living *C. (C.) lucidus*. Although the fossil specimens from Cerro Gallina do not preserve color patterns, the raised spiral threads distinguish it from cones of similar profile, such as *Conus vittatus*. For complete synonymy and discussion, see Hanna (1963:56–58).

DISTRIBUTION.—Baja California, Mexico, to mainland Ecuador and the Galápagos Islands, living; Galápagos Islands, fossil.

GEOLOGIC OCCURRENCE.—Pleistocene–Recent.

LOCALITIES.—CAS Locs. 61224, 61225, 61234, 61235, 61237.

MATERIAL COLLECTED.—Seven specimens.

FIGURED SPECIMEN.—CAS Geology No. 61410 (Loc. 61225).
Length 25.2 mm; width 14.3 mm.

Family TEREBRIDAE

Genus *Terebra* Bruguière, 1789

Terebra armillata Hinds, 1844

(Not figured)

Terebra armillata Hinds, 1844:154; Keen 1958:490, fig. 956; Keen 1971:672, fig. 1522; Bratcher and Burch 1971:556–557, fig. 27.

DISCUSSION.—Two fragmentary terebrid specimens from Cerro Gallina, each consisting of approximately two whorls, have proportions and sculpture that place them within the range of variation that Bratcher and Burch (1971) described for this species.

DISTRIBUTION.—Baja California, Mexico, to Peru and the Galápagos Islands, living; Galápagos Islands, fossil.

GEOLOGIC OCCURRENCE.—Pleistocene–Recent.

LOCALITY.—CAS Loc. 61225.

Terebra plicata Gray, 1834

(Not figured)

Terebra plicata Gray, 1834:61; Keen 1971:682, fig. 1556.

DISCUSSION.—This species is represented in our collections by a single specimen consisting of one whorl. The sculpture, although worn, is sufficiently distinctive to place it within the range of variation in CAS specimens of living representatives of the species.

DISTRIBUTION.—Central America to the Galápagos Islands, living; Galápagos Islands, fossil.

GEOLOGIC OCCURRENCE.—Pleistocene–Recent.

LOCALITY.—CAS Loc. 61236.

Family TURRIDAE?

(Not figured)

DISCUSSION.—Two poorly preserved specimens from Cerro Gallina are tentatively referred to the Turridae.

LOCALITY.—CAS Loc. 61236.

APPENDIX

Locality Data

CERRO GALLINA, ISLA SANTA CRUZ (00°42'50"S; 90°29'50"W)

CAS 61224. Low tuff cliff just above beach level, west side of small cove on west side of Cerro Gallina. (Field no. G-1-82.) Collected by W. D. Pitt and J. H. Lipps, 2 Feb. 1982.

CAS 61225. Southeast side of Cerro Gallina at beach on east side of small cove bounded by tuff cliffs, including all exposures along sea cliff from gully running into head of cove eastward to last accessible cliffs (about 30 m). Fossils occur as isolated shells in tuff. (Field no. G-4-82.) Collected by W. D. Pitt, L. J. Pitt, C. S. Hickman, J. H. Lipps, M. J. James, 2 Feb. 1982.

CAS 61226. Stratified, water-worked unit in massive tuff, at head of beach in tuff beds gently sloping across top of beach immediately east of gully entering head of cove. (Field no. G-5-82.) Collected by C. S. Hickman and W. D. Pitt, 2 Feb. 1982.

CAS 61227. Small ridge trending south toward beach, just above sea cliff on east side of cove and just above CAS 61226 (Field no. G-5-82). No field number. Collected by J. H. Lipps, 2 Feb. 1982.

CAS 61233. Approximately 12 m above sea level on second ridge north of beach in gully entering head of cove. (Field no. G-9-82.) Collected by C. S. Hickman, 2 Feb. 1982.

CAS 61234. Halfway up gentle ridge to sharp break in slope leading up to peak of Cerro Gallina: ridge is third one north of beach in gully and causes a bend in the gully where it intersects it. Approximately 20 m above sea level. (Field no. G-6-82.) Collected by J. H. Lipps, 2 Feb. 1982.

CAS 61235. Massive outcrop of tuff approximately 40 m above sea level on same ridge described in CAS 61234. (Field no. G-6-82.) Collected by J. H. Lipps and C. S. Hickman, 2 Feb. 1982.

CAS 61236. On same ridge as CAS 61234 (Field no. G-6-82) in massive tuff above principal break in slope leading to top of Cerro Gallina. (Field no. G-8-82.) Collected by J. H. Lipps and C. S. Hickman, 2 Feb. 1982.

CAS 61237. On ridge trending south from top of Cerro Gallina, approximately 20 m below summit. (Field no. G-10-82.) Collected by J. H. Lipps and C. S. Hickman, 2 Feb. 1982.

CAS 61238. Tuff cliff on southeast side of Cerro Gallina, on northwest side of sandy beach approximately 1½ m up sea cliff. (Field no. G-3-82.) Collected by C. S. Hickman and W. D. Pitt, 2 Feb. 1982.

CERRO COLORADO, ISLA SANTA CRUZ (00°34'30"S; 90°10'20"W)

CAS 61228. Red tuff hill opposite South Plazas Island, northeastern coast of Santa Cruz. Isolated fossils collected on north and west slopes of cone. (Field no. G-56-82.) Collected by W. D. Pitt, C. S. Hickman, J. H. Lipps, 11 Feb. 1982.

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